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PROCEEDINGS OF COMMENCEMENT 1908

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PRESIDENT'S OFFICE.



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PROCEEDINGS OF COMMENCEMENT

THE EIGHTY-THIRD COMMENCEMENT of the College was very largely attended. The exercises of Commencement Week opened with the delivery of the Sermon before the Undergraduates by the Rev. Arthur Wheelock Moulton, '97, Rector of Grace Church, Lawrence, Mass., on Sunday morning, June 14th, at Trinity Church. On the evening of that day the Baccalaureate Sermon was preached by the Rev. William Thomas Manning, S.T.D., Rector of Trinity Church, New York.

THE COMMENCEMENT DAY EXERCISES took place on Wednesday, June 17th. The Latin Salutatory was pronounced by Walter Hetherington Durfee. The Phi Beta Kappa Oration by Professor Arthur Gordon Webster, Ph.D., D.Sc., LL.D., of Clark University, followed. It appears in full in this Bulletin. The Prizes were then announced, including six of the eight intercollegiate prizes awarded for 1908. Thereupon the baccalaureate degrees were announced and conferred, and the degree of Master of Arts in course was conferred upon Edward Guy Nellis, A.B., '06.

The recipients of Honorary Degrees were then individually presented to the President by Professor Milton Haight Turk in the following words, the President and Faculty standing during the last announcement:

"For the honorary degree of Doctor of Sacred Theology, I present to you the Rt. Rev. Charles Edward Cheney of Chicago, an alumnus of this College in the class of 1857. Through a long and very active career Bishop Cheney's

influence has extended beyond the confines of his own denomination, while he has also combined with the arduous tasks of his high office much fruitful effort in literature, as his numerous published writings attest. The old College is happy in the possession of such a son; more happy in the opportunity to welcome him home after half a century; and most happy in the privilege of cementing the old relationship with this new tie."

"I have the honor to present to you for the degree of Doctor of Sacred Theology, *in absentia*, the Rev. William Thomas Manning, Rector of Trinity Church, New York, and the Baccalaureate Preacher of this year. Dr. Manning several years ago received this degree from his Alma Mater, the University of the South. He was for some time professor of dogmatic theology in that institution, and thereafter taking up parochial work, won very early a position of eminence in the Church. Of his singular eloquence and fascination as a preacher we all have knowledge. On the grounds of both scholarship and distinguished service the suitability of this degree is obvious, and it was bestowed by the action of your Corporation some months since on such grounds alone. The recent election of Dr. Manning to the Rectorship of Trinity Church, however, has lent a special fitness to this act, enabling us at the threshold of his pastorate to welcome as a son of this College the head of the great parish to which the College owes an historic debt."

"For the same degree of Doctor of Sacred Theology, *in absentia*, I present to you the Rt. Rev. Robert Lewis Paddock, Missionary Bishop of Eastern Oregon. Bishop Paddock's work for his church and his country has but begun, yet it has already been a great work. As Vicar of the Pro-Cathedral in Stanton St., New York, he took

a stand in defense of the homes of his people which was one of the chief causes of the overthrow of a most corrupt political ring. Called later on to a church deserted by its well-to-do parishioners, he built it up anew as a home for the poor people who had come into the neighborhood. Such labors as these need, I trust, no graces lent by the pen and the lamp to commend them to academic honor. This College is surely fortunate in the opportunity to approve by whatever distinction the claims of a noble public service."

"For the degree of Doctor of Letters, I have great pleasure in presenting to you the Phi Beta Kappa Orator of last year, Professor Robert Mark Wenley of the University of Michigan, Doctor of Philosophy and of Laws of Glasgow, and Doctor of Science of Edinburgh University. Dr. Wenley's foreign degrees, his brilliant professional career and his many and weighty contributions to the literature of his science can well dispense with the recognition they so amply justify, but his work has for many years been among our people, and it is becoming that an American college should extend a maternal hand to one who is a constant inspiration to thousands of American youth. In this place, too, where a year ago he spoke to us with such eloquence and charm, we may be permitted to rejoice that Hobart has a new Doctor who has irradiated Science with humor and married Philosophy to the joy of life."

"For the degree of Doctor of Laws, I have the honor to present to you the Phi Beta Kappa Orator of this day, Professor Arthur Gordon Webster of Clark University, Doctor of Philosophy of the University of Berlin and Doctor of Science of Tufts College, a very distinguished physicist and author of many treatises and papers in

that department. We, who have seen today a little picture of his mind, know that Dr. Webster has a word not for physicists nor for scientists alone, but also for men. Scientific achievements so brilliant, joined to so real a human interest, lend surely to the framework of things moral that support which justifies for men of various callings the title of Doctor of Laws."

"For the honorary degree of Master of Arts I had hoped to have the privilege of presenting to you Mr. Charles B. Dalton, of New York, upon whom this degree was conferred by vote of your Board in January last. Mr. Dalton died at his home in New York on the 8th of this month. In several monographs, and especially by his Gould Prize Essay on "Bible Versions," he had won acceptance as a scholar and writer, but the life now so untimely ended was devoted chiefly to the work of teaching. The diploma he should have received this day must now become the property of his widow, and the honor that Hobart College had intended as an encouragement to further achievement must remain the last earthly evidence of the public approval of his fellow-men."

With the conferring of the honorary degrees and the benediction the Exercises closed.

THE ALUMNI DINNER was held in Coxe Hall as usual and was very well attended; '93, '98, and '03 held reunions. Four long tables besides the speakers' table were filled. Rev. Lewis Halsey, '68, acted as toastmaster, introducing President Stewardson, Bishop Cheney, '57, Professor Webster, Professor Wenley, Rev. G. R. Brush, '92, Dr. C. O. Boswell, '93, Mr. W. G. Raines and H. R. Drummond, '08.

PHI BETA KAPPA ORATION

Brethren of the Phi Beta Kappa:

It is not so many years ago that the proposal to invite a professed scientist to deliver the Phi Beta Kappa address before a chapter of a denominational Christian college would have caused much grave shaking of heads, if not absolute opposition. Sensible as I am of the honor conferred upon me by the invitation to address you today and conscious as I am of my inability to worthily requite it, I feel that I can not better fulfill the duty devolving upon me than by inviting your attention to the point of view of a Scientist, and by an examination of the question, what is Science, what does it hope to do, what are some of its achievements and is it the present and future representative of that Philosophy which our motto recommends to us as the guide of life?

One of the greatest of living scientists, Lord Rayleigh, places next to the title page of his collected writings the verse, "The works of the Lord are great, sought out of all them that have pleasures therein." Inspired by so good an example, I take a similar text from the book of Job, "Canst thou by searching find out God?" A distinguished scientist of a century ago, the celebrated Count Rumford, left a considerable sum of money to the American Academy of Arts and Sciences in Boston for the foundation of a prize for discoveries in light and heat, preference being given to such discoveries as shall, in the opinion of the Academy, tend most to promote the good of mankind. In the discussion of this award, the question has often arisen in my mind, what is the good of mankind, and how may we best promote it? If we go back in

imagination some thousands of years, we shall find primitive man dwelling in caves or other dwellings not fashioned by himself, ignorant of fire and the cultivation of the earth, occupied with nothing save the procuring of food, and the defense of himself against wild animals and his equally savage human neighbors. He then had no needs but these, and his only good was subsistence. He did not pay much attention to nature, nor ask himself why he should attempt to subsist. Later he learned to shape rough tools and weapons from stone and to use fire, so that he became differentiated from the beasts, and later still he learned the use of metals. During these times, his chief interest was still subsistence, although to the need of food was now added that of a constructed dwelling. By this time he paid some attention to the phenomena of nature, which he believed to be caused by a large number of genii, spirits or imps, possessed of feelings and passions similar to man's, who must be propitiated, in order that they might disturb him as little as possible. Thus originated nature myths and early religions, and after the struggle for existence had become less acute, and community life became possible, morals began to be developed. It is impossible to settle in what order the phenomena of nature began to be perceived by man, but it seems to admit of no doubt that the first thing to force itself upon his attention was the periodic sequence of day and night, the rising and setting of the sun and moon, and the changes of the seasons. Whether these presented themselves to his attention in any aspect except as they favored or interfered with his activities we cannot tell, but there is no doubt that he took advantage of them. Finding that a fallen tree would float, and that by means of it he could cross a river, he eventually hol-

lowed it out into a boat, and took advantage of the wind to save himself the labor of propulsion. Far later must have come the ability to take advantage of the wind when blowing in the wrong direction, and thus practically to command this natural phenomenon. With the development of agriculture man's dependence on the sun and its changes evinced in the change of the seasons and the recurrence of crops must have led him to take careful notice of the heavenly bodies. At any rate we find the shepherds of Chaldea becoming conscious that the starlit heavens under which they watched their flocks were not random floods of luminosity, but that the heavenly bodies were marshalled in regular array, never quitting their fixed positions relatively to one another, with the exception of a very few, which seemed to wander at random. These wanderers or planets were closely associated with the destinies of man, and finally were associated with the attributes of gods in the Greek and other mythologies. Of the uplifting effect of the early astronomical perceptions we get an example in the magnificent songs of the book of Job.

The perception of the regularity of which I have spoken in connection with astronomical phenomena is the beginning of the impulse to seek for such regularity in phenomena in general, irrespective of the direct influence of such regularity on our lives. When the means of existence had become relatively easy, and civilization had developed so far that men were not continually at war with their fellows, it became possible to devote part of the time to contemplation and to the asking of unnecessary questions merely for the pleasure of so doing. Thus we find the Greeks, so far advanced in the perception and cultivation of beauty, no less advanced in the cultivation

of the beauties of the intellect, and in the contemplation of the nature of the world about them. We find them pursuing inquiries into the relations of number and of space, going far beyond the elementary properties of lines and of angles, and pushing the geometry of the sections of the cone to a point which was not passed by for much more than a thousand years.

Whether the Assyrians and Egyptians, who had preceded the Greeks in the study of number and of space, had been led thereto merely by the needs of trade, for the operations of exchange, the measurement of ground, and the finding of the ways from place to place, or by other less practical reasons, it is certain that the Greek mathematicians pursued their studies for the pleasure that they obtained therein, in the contemplation of the unchanging relations with which they were confronted, and the satisfaction of that intellectual curiosity which is such a legitimate spring of human action, and which has since become a mastering human passion. With the Greeks this curiosity "*rerum cognoscere causas*" manifested itself in the desire to know the origin of man and his ultimate destiny, and all these objects of inquiry were pursued together by the philosophers. The natural philosopher proper had not yet made his appearance.

After the fall of the Greeks and Romans, there succeeds the night of the dark ages, when the impulse to inquire into the nature of things seems to have totally died out, or was preserved only among the Arabs. Whether the gradual conversion of the world to Christianity, the increase of the temporal power of the church, and the intense desire that the teachings of a rigidly crystallized theology should be preserved unaltered, was the cause of this, I do not propose to discuss, suffice it to notice the

coincidence. Finally after a thousand years of this intellectual darkness came the revival of learning, and with it what we may characterize as the dawn of science. For the learning of the Greeks, and their method of approaching the study of natural phenomena, was not characterized by what we now call the scientific method, it was rather the study of their own minds than of the workings of nature that they engaged in. The idea of finding out, not how nature ought to work, but how she actually does, by putting questions directly to her, placing her in a position where she can work her way, and cannot avoid giving an intelligible answer, is the invention of modern times, and we may almost date it from Galileo, although we cannot ignore the great achievements of Copernicus, Kepler and Tycho Brahe. When Galileo, to refute the theories of the Aristotelian philosophers of the day as to the way in which bodies should fall, dropped the two weights from the tower of Pisa, he laid the foundation of the modern experimental method, and sounded the death-knell of the old unscientific philosophy. However, the difficulty of convincing the conservatives of the propriety of this method may be judged from one of the arguments against the existence of Jupiter's moons, discovered by Galileo with his newly-invented telescope. Francesco Sizzi, a Florentine astronomer, argues thus:

"There are seven windows in the head, two nostrils, two eyes, two ears and a mouth; so in the heavens there are two favorable stars, two unpropitious, two luminaries and Mercury alone undecided and indifferent. From which and many other similar phenomena of nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets is

necessarily seven. Moreover, the satellites are invisible to the naked eye, and can have no influence on the earth, and therefore would be useless, and therefore do not exist. Besides, the Jews and other ancient nations as well as modern Europeans have adopted the division of the week into seven days, and have named them from the seven planets, now if we increase the number of the planets, this whole system falls to the ground."

The second argument against the existence of satellites because of their uselessness to man, is a sample of the attitude long taken that man is the principal object in nature, and that all nature is for the purpose of aiding in his salvation. This view, though ancient, as we have seen, is not yet entirely extinct. What Galileo had to suffer at the hands of the Church for his heretical views regarding the solar system, and how, a feeble old man, he was obliged to recant, is a familiar story.

Of the time from the foundation by Galileo of the science of mechanics and its erection by Newton into a grand and all-embracing system, to the origin and development of the other sciences, it is not my purpose to speak. From that time to this there have always been a class of devoted searchers after truth, not counting the cost of sacrifice or persecution, content if by their efforts they may succeed in throwing a little light upon the mysterious ways of nature. Philosophies and religions may change, governments may rise and fall, but the work of these men goes on. During the terrible scenes of the French Revolution, when Fouquier Tinville said, "The republic has no need of savants," and the head of Lavoisier fell into the basket of the guillotine, the work of the great chemist revolutionized men's ideas, and while France was by turns under the Directory, the Consulate, the Empire,

and the Restoration, the glory of French science remained unimpaired. During the life and death struggle of France against Prussia, the Germans beleaguering Paris offered free passage through their lines to the astronomer Jansen, who wished to leave France to observe an eclipse of the sun, but he being a Frenchman as well as a scientist characteristically refused the permission, and preferred to make his escape in a balloon. Nowadays, we have progressed considerably in such matters, and the interests of science are admitted to be international. A few miles below Paris at Sévres is situated the laboratory of the International Bureau of Weights and Measures, in which is carried out the work of the determination and inter-comparison of the fundamental standards of measurement for all the countries of the world, and the ground on which it stands is neutralized by treaty. If the Germans should once more beleaguer Paris, and the neighboring Chateau of St. Cloud should once more come under their guns, this spot of ground would be untouched, a tribute to the civilizing power of science. The institution of international scientific congresses, now of so common occurrence, is another symptom. Within a few weeks the fourth international congress of Mathematics was held in Rome, and five hundred mathematicians from all over the world met in the palace on the Capitoline Hill in the presence of the King of Italy to discuss the progress of Mathematics, while at their feet lay the Forum, to emphasize the contrast between the old and the new dispensation. Why should the King of Italy lend his presence to such a gathering, and what has the advancement of pure mathematics to do with the welfare of man?

In order to answer this question, let us turn to the larger one, what is science, what are its methods, and

what its purposes? Science has to do with the arrangement of knowledge, that is to say with the classification of what we recognize to be truth according to an orderly system. The scientist proceeds upon a number of assumptions, which he justifies by their results. He does not stop to consider, like the metaphysician, the question of the reality of the external world, and whether it exists outside of his consciousness. These, to him, are not questions to be answered, but arrangements of words, in which he is not interested. He assumes that the world exists, and furthermore that it is capable of being understood, that is that there is a correspondence of some sort between the operations of external nature and the operations of his own mind, in other words, that there are classes of phenomena which may be described by certain terms in common, and it is the business of science to find the descriptions of these phenomena, in as comprehensive a manner as possible. This is now generally admitted to be the business of Science, the exact description of phenomena, the question of cause and effect being rather a metaphysical one. For instance, it is considered the proper business of mechanics to say, not that certain forces produce certain motions, which is merely to define those forces, but to describe the various motions that we actually find in nature, and find what they have in common. As a concrete example, it has been known for an indefinite period that all bodies when unsupported near the earth, fall to the ground. A later manner of stating the same thing is to say that the earth attracts all bodies, but this is to add absolutely nothing to our knowledge, but merely to change the terms of our description, making no contribution to science. In order to accurately describe this phenomenon, we are obliged to say that

bodies fall with an acceleration directed vertically, which is the same in amount for all bodies whatever. We have now added something definite to our knowledge, of a quantitative nature, involving a number of concepts, namely those of acceleration and velocity, these depending on space and on time, all of which must be familiar to us before we can make use of this description, to say nothing of the notion of number, and its application to measurement. It is immaterial to the scientist how we arrive at the concepts of space and time, suffice it to say that we do arrive at them, and find it possible to agree on a mode of measuring them. We then arrive at a means of defining velocity by means of the space described in a given time, and of defining acceleration or hurry as the velocity gained in a certain time, while in order to make these definitions precise we are obliged to make use of the notions and terminology of the differential calculus. But when we have done this we have obtained something which we believe to be true, a generalization that holds irrespective of time, place, or observer, in short, a scientific truth, or law. This we can leave behind us, and we may be forgotten, the law never. This was what Galileo did for falling bodies, and Newton for the universe in general. We have thus, in substituting the accurate for the nebulous, been obliged to go from the familiar to the unfamiliar. The achievement of Newton is generally understood in the nebulous manner. Newton made the notion of acceleration a fundamental one, and applied it to all bodies. Fixing the attention upon any pair of bodies in the universe, say the sun and a planet, he showed that these two bodies are accelerated towards each other, that the two accelerations are not equal, but in a fixed ratio, while their absolute values depend, not on the

velocities of the bodies, nor upon their absolute positions in space, but solely upon their distance apart, and that their measures are inversely as the square of that distance. Fancy the tremendous significance of this generalization, and of how little importance in comparison is the name of gravitation, or the question of its cause. The thing is that bodies do move in such a manner. This then is what we mean by a law of nature, the description of a class of phenomena in the simplest exact manner. Let us pass from these familiar matters to another that is less so, but in the same line. The public is at the present moment much interested in the gyroscope and its applications, whether to stop ships from rolling, for the prevention of sea-sickness, or to enable cars to balance on a single rail. The action of the gyroscope is said to be mysterious, others say it violates the law of gravity, since when supported on one end, it does not fall. For mysterious read unfamiliar. In this case the description of the motion is complicated, and we are obliged to use some refinement. If we consider each small particle of the revolving top, find its velocity, represent this in direction and magnitude by a line, represent the area of a triangle with this as base and the fixed point of the top as vertex by another line perpendicular to the plane of this triangle, and then compound or add all such lines for all the particles of which the top is formed, we obtain a line whose end describes a curve in a horizontal plane. This irrespective of the apparently irregular movements and gyrations of the top, now up, now down. Thus out of apparent irregularity and complexity comes regularity and simplicity, and all is found to take place according to the fundamental laws of acceleration established by Newton. Thus we have achieved the description, in a simple man-

ner, although to do it we have been obliged to make use of numerous conceptions, including the method of the integral calculus. We have here an example of how mathematics has developed, being frequently led to form new conceptions in order to describe phenomena existing in nature. Mathematics is accordingly far from having sprung, like Athena, full-armed from the head of Zeus or of man.

The point of view of the scientist, as I have here described it, is possibly not that which it is ordinarily supposed to be. The nineteenth century has been pre-eminently the century of science, and with many of its results the world is familiar. We, in this country, pride ourselves on our applications of science, our great engineering works, transportation systems, telegraphs, telephones, electric lights, automobiles, phonographs, and the many other tangible evidences of man's acquaintance with and power over nature. It is a commonplace to dwell upon the importance of these in our daily lives, as well as of the results of biological science, the prevention of disease, the stamping out of yellow fever, the improvement of domestic animals and of flowers and fruits, the protection of our forests and farms from the inroads of their natural enemies, and the multiplication of our resources for obtaining food. These are the results of science which are most plainly before our eyes, and it is not strange that we consider ourselves a scientific nation. No doubt this applied science is an important aspect of science in general. But it is not on account of these triumphs of applied science that I bespeak your interest in science in general. Let us suppose that the advance in science, the success of socialism, or what not, has given all the comforts of life to every one of us, has furnished

every working man not only with three acres and a cow, but with sanitary plumbing, steam heating, hot and cold water, cold brine for refrigerator, milk and beer laid on in pipes to every dwelling, electric lighting, heating, and power for the few remaining domestic necessities, a telephone for communication and for the enjoyment of contemporary music, and phonograph for that of the past, with an automatic piano and an automobile, and that the hours of labor have been reduced to four, will universal happiness then reign? I fear not, if this is all. For man shall not live by bread alone. With the amount of leisure that I have supposed, shall he not invite his soul, not by loafing, but by the contemplation of the world around him, and the endeavor to make himself the possessor of some of its secrets. It is here that the satisfying power of science appears, for the possession of the scientific spirit not only leads one to an optimistic outlook upon the world, but stimulates one to continual further conquests of knowledge, and to endeavors to bring life in general into a more perfect development, in accordance with the scheme of the universe as it appears to his enlightened mind. At the same time it kindles the imagination, for science no less than poetry demands imagination in a very high degree, and moreover this imagination must be continually guided by the reasoning power, in order to lead to any advance in the comprehension of the scheme of nature.

It is the satisfaction of man's reasonable intellectual curiosity, then, that I consider the main justification of science, and the moral influence that the scientific method will have upon his life. Can anything have a more ennobling effect than the pursuit of truth, especially when all other considerations are sacrificed to it? I do not

need to call the roll of the noble army of martyrs of science, from Galileo and Giordano Bruno to the devoted surgeons who laid down their lives in the study of yellow fever in Cuba, of the plague in India, Russia, and Austria, or of the sleeping sickness in Africa. I confine myself to the more humdrum and unheroic career of the investigator in his laboratory or in the field. In order to make my point, let me briefly consider, what is the scientific method, that it should produce such desirable results? In the first place, it is actuated solely by the desire to find out the truth, with no reference whatever to preconceived prejudices, and with utter disregard of authority or conservatism, unless backed up by arguments directed to the reason. The scientist first observes a certain number of facts, and having convinced himself that they may be classified together proceeds to form a simple means of relating them, forming a hypothesis in order to do so. It is here that the imagination is called into play, if not before, for in many cases the imagination must be used in order to give an idea of what facts to observe in order that they may be classified together. As an example of the collection of facts in an absolutely unscientific manner, I may mention an amusing character described by Stevenson in his story, "The Wrong Box," an old gentleman who delighted in giving lectures to workingmen, and who would state in the same breath the distance of the moon from the earth, the population of the great cities, the velocity of sound, the proper constituents of diet, and so on. The collection of facts as one collects postage stamps does not constitute science. The knowledge must be collected into a theory, a much abused word which should have its Greek signification as a mode of looking at things, a point of view, that is to say,

from which they may all be regarded. As another example of an unscientific point of view, I will relate a story told me by a distinguished American geologist, who had spent a summer in Wales examining the structure of the river valleys there, with one object of confirming or disproving a theory as to erosion produced by glaciers. Describing his work to a well known English geologist, a former president of the Geological Society, he was astonished at receiving the reply, "I was *taught* that ice did not erode." Such a man evidently needed a scientific bishop, if not indeed a pope.

In the collection of facts, we are confronted with two possibilities. In one case we may control the phenomena we wish to observe, and isolate the effects we wish to consider more or less from others. Thus, if we wish to study the effect of change of volume on the pressure of gases, we may confine the gas in a vessel from which it can not possibly escape, and if we suspect that its pressure depends on its temperature, we may place the vessel in a bath whose temperature is maintained without variation. On the contrary if we wish to study how much heat is required to raise the temperature of a body by a certain amount we must make sure that no heat escapes from it during the process. This we cannot do, for though we surround the body with poorly conducting blankets, some heat is bound to escape. We must, therefore, find out how much, and make a correction for it. Such are the usual processes of the physicist and they may be carried on in the laboratory. If he wishes to investigate the motion of the tides, however, he cannot control them in the slightest, but he takes advantage of their continual recurrence to find out their minutest details by measuring their height at various times and places, all of which he

fits into a theory indicated by mechanics. Far different is the case of the geologist, who can neither control the magnificent phenomena which concern him, nor even see them repeat themselves.

He must draw his conclusions regarding processes requiring millions of years from observations of the surface of the earth during a short time, drawing at most upon the experience of a few centuries. Nevertheless, if he cannot see the rocks forming, and hardening from a melted state, he can make experiments upon them in the physical laboratory, in the electric furnace he can produce temperatures sufficient to melt any rocks, and although he cannot examine their behavior at such pressures as are found at the center of the earth he can at any rate cause pressures several thousand times as great as that at the earth's surface, and thus he can infer many of the properties of rocks as they were actually formed. The Carnegie Institution of Washington has just completed a geophysical laboratory in that city for the study of such problems as these, and all similar ones having to do with the physics and chemistry of the earth's crust. In order to approach the question of the age of the earth, as was done by the late great physicist Lord Kelvin, it was necessary first to imagine a mode by which the effect of the earth's age upon processes now going on could be determined. This was done by Lord Kelvin by finding out how long it would take a sphere of the constitution of the earth to cool down from the temperature of molten rock to the temperature that the earth now has. In order to do this it is necessary first to investigate the mathematical laws of the conduction of heat, as was done a century ago by Fourier, and then to measure how fast the temperature increases as we go below the earth's surface, for

the longer the cooling has been going on the more gradual will be the increase in temperature as we go toward the center. This is a typical scientific investigation, requiring first the inventive stroke of imagination, then, the development of a theory involving the hypothesis that during geological ages the laws of heat conduction have been immutable, then the observations of present temperatures and of the conductivity of the materials composing so much of the crust as can be reached. If the results reached of an age of from twenty to a hundred million years are astonishing, how are they to be gainsaid? Only by attacking one of the processes involved, either the theory, the measurements, or the sufficiency of the data, for no one would now think of attacking the hypothesis of the immutability of natural processes.

As a further example of the investigation of the large scale processes of nature, may be mentioned the very new science of astrophysics. Until recently astronomy was content to observe the positions of the heavenly bodies, to find out the motions of such as moved, and to place these in the scheme of celestial mechanics, according to the law of Newton. An idea of the precision now arrived at in astronomy of position may be obtained from the statement that it is possible to predict the moon's place one hundred years ahead so that the time of an eclipse shall be given within three or four seconds of time, so that the error is not over one part in one billion, this being probably the greatest accuracy known to modern science.

But since the invention of the spectroscope about fifty years ago it has become possible to find out the physical constitution of the stars, what substances they contain, which of them are old and which young, and in short to

examine properties not dreamed accessible to our knowledge fifty years ago. There has been established within the last three years by the Carnegie Institution an observatory placed on the summit of Mt. Wilson in California for the exclusive study of the physical character of the sun. Here the sun is photographed by the most powerful telescopes and not only by all of its light, but by various portions of its light given out by hydrogen gas, by metallic calcium and iron vapors, so that we obtain photographs of the clouds of various elements constituting the different parts of the solar envelope. Thus the sun, which is a typical star, is placed in the grand story of stellar evolution. I was recently asked, of what use is all this, and what justifies the expenditure of the hundreds of thousands of dollars there expended. To this I must answer that if by use is meant adding to the comfort or convenience of living, or of amassing money, I know of none, but that if we mean contribution to the welfare of mankind in the larger sense of which I have spoken, then I know of no investment of the millions that Mr. Carnegie has so lavishly given away that can be considered more profitable. In my opinion the man that has no appreciation of the beauties of such investigations is like him who hath no music in his soul, fit for treasons, stratagems and spoils.

As a final example of the scientific method, involving the use of the imagination in a very high degree, with the successful employment of a daring hypothesis, I shall give a short account of the development of the theory of light and electricity during the last century. It was found over two hundred years ago, that, as suspected by Galileo, light did not pass instantaneously from one point to another, but required a sensible interval to travel,

although it would go seven and a half times around the earth in one second. A natural hypothesis as to the nature of light then was that it was composed of small particles projected from luminous bodies with this great velocity, which on striking the eye produced the effect of light. This theory was held by Newton, and held the ground for a century. But by the beginning of the nineteenth century phenomena had been observed that could not be explained by this corpuscular hypothesis, such as the phenomena of interference, or the production of darkness by the addition of lights, and it became necessary to adopt a new hypothesis. At the same time, physics was beginning to experience the tendency which is now its most prominent characteristic, namely the desire to explain all phenomena as motion, that is to reduce all physics to mechanics, this being the simplest possible mode of description yet known. Thus the idea was put forward that light was a phenomenon of wave propagation, and as waves can take place only in some medium, the vehicle in which the waves are propagated was given the classic name of the ether. The existence of the ether is then a pure hypothesis, the fruitfulness of which we shall see. The ether is defined merely as that which undulates, being merely a subject for this verb. The wave theory had been put forward by Huygens, a contemporary of Newton, and had with wonderful success been made to explain the double refraction of light in certain crystals, such as Iceland spar, through which an object is seen double. The chief proponents of the wave theory were, however, Thomas Young and Augustin Fresnel, who correctly described the transverse vibration of the particles of the ether in a ray of light. Fresnel, by a brilliant mathematical generalization of the construc-

tion of Huygens, was able to find the shape of the wave surface in all crystals, that surface which in air is a sphere surrounding the luminous point, but in a doubly refracting crystal, where the two rays into which the light is broken travel with different velocities, is a surface with two separate sheets. By the careful study of the geometry of this surface Sir William Rowan Hamilton was able to show that there are two directions in which a ray entering a crystal would be broken up not into two rays as usual, but into an infinite number forming a cone of rays. This discovery of conical refraction, a phenomenon which had never been observed, was and always must remain a startling example of scientific prediction, which is the surest criterion of the success of a hypothesis. The phenomenon was observed by Hamilton's friend Lloyd and found to exist exactly as had been predicted by Hamilton. We can imagine the emotions of these two scientists as this experiment was carried out, and the thrill of exaltation which Hamilton must have experienced when his imaging was verified must have partaken of the nature of the ecstasy which the poet or the inspired seer is supposed to experience.

The theory of light, as conceived by Fresnel, although explaining optical phenomena as motion, did not give a thoroughly mechanical description of the ether. This was the work of George Green, who showed that if the ether had the properties, not of a liquid or gas, but of an elastic solid like a jelly, it would afford a correct explanation of the most of the phenomena. In the meantime, the epoch-making discoveries of Faraday in electricity and magnetism had been made, particularly that of the induction of currents, or the production of current in a closed wire circuit by the change of current in another

circuit at a distance, upon which discovery the construction of all our dynamos for producing current depends. Faraday set himself to grapple with the question which had agitated Newton, how can a body act where it is not, and had been led to the answer that it cannot, but that action must be transmitted from particle to particle of some medium. What is the medium that transmits electric and magnetic actions. The answer to this question was given by the great English physicist James Clerk Maxwell, in a remarkable paper published in 1864. Here again, Maxwell was guided by the attempt to reduce the subject of electricity to mechanical principles, that is to make it depend on the laws of motion. In carrying out this attempt he was led to the hypothesis that the medium that transmits the electric actions was nothing else than the luminiferous ether. Mark the wonderful simplification of the problem when the same hypothesis does for the two fields of light and electricity, hitherto considered independent. For the conclusion of Maxwell was that electrical actions were propagated with a finite speed, and that this speed was equal to that of light, and finally that light itself was but a species of electro-magnetic vibration. It is worthy of note that Maxwell never himself saw the experimental verification of his theory, he never succeeded in producing electrical waves. This was done in 1887 by Heinrich Hertz, who not only succeeded in producing these waves, but in measuring their velocity, and showing it to be identical with the velocity of light. What a triumph for Maxwell, nine years dead. I well remember the sensation produced by the publication of Hertz's researches. A student in Helmholtz's laboratory in Berlin, I was especially pleased to see Maxwell's theory, till then not generally believed

in Germany, verified and given the character of prophecy by a German and a pupil of Helmholtz. Could Maxwell today see the application of his electric waves in wireless telegraphy for the saving of lives and the communication of news at sea I doubt whether his elation could be greater than it would have been at the confirmation of his theory of electricity. As an example of how this problem has seized the minds of the great imaginers, I may quote the late Lord Kelvin, who stated on the occasion of his jubilee as a professor at Glasgow, that there had not been a day for forty years when his mind had not dwelt on the problem of the constitution of the ether. But I have not quite finished with this fascinating subject, for Maxwell not only showed that electrical actions were transmitted with the speed of light, but he showed *how*, namely by stresses in the ether or in bodies under the action of electric fluids, and thus he showed that a beam of light would exert a certain pressure on a body on which it impinged. This pressure would be enormously small, Maxwell calculated that sunlight would cause a pressure of about one one hundred millionth of a pound per square foot of a black body, but this has again received a brilliant verification within the last half dozen years, the pressure being observed and measured by Lebedeff in Russia, and by Nichols and Hull in this country, in a research constituting one of the most original products of American Science.

Finally the attempt to construct a mechanical model of a source of light has led Professor Lorentz of Leyden to imagine it as the vibration of a very small charge of electricity, a consequence of which was the conclusion that a source of light placed between the poles of a magnet would have its spectrum lines changed, a discovery

made by Zeeman. For this confirmation of Lorentz's theory, one of the Nobel Prizes in physics was divided between him and Zeeman. The theory of electricity propounded by Lorentz, which supposes that all electric charges are composed of minute atoms of electricity, or electrons, all alike, thus furnishing a new conception to physics, has been brilliantly illustrated by the newly discovered phenomena of the element radium and its relations.

I feel that I have said enough to show the nature of scientific research, its use of the imagination, its inspiration to the worker, and its never-ending pursuit of the ideal. I have not spoken of the great doctrine of evolution, which has served to arrange all the sciences according to a single principle, preferring to choose my illustrations from ground more familiar to me. If I had time I should like to urge the attractions of the scientific career upon those who are about to choose, and the duty of young men toward our country, to strive to put her in the front rank in pure science which she has not yet attained. I should like to dwell on the fact that though few of us may experience the thrills that come from the achievements of genius, there is a surer satisfaction in being one of those who also ran, than in any race in which but one receiveth the prize. To the layman I should like to commend the scientific spirit as one of humility, as one of patience, as one of single-minded pursuit of an ideal, without fear of the result. It is the spirit described by Kipling:

And only the Master shall praise us, and only
the Master shall blame;
And no one shall work for money, and no
one shall work for fame;
But each for the joy of the working, and each,
in his separate star,
Shall draw the thing as he sees it for the God
of things as they are!

And yet it must be admitted that the scientist has not succeeded in communicating his enthusiasm to every one. In face of the triumphs which I have described, which might be multiplied indefinitely, how absurdly unjust seems the phrase, the Bankruptcy of Science, invented, I believe, by the celebrated French critic, Ferdinand Brunetière, in a famous polemic against science, which he accuses of not having fulfilled its promises. Under the influence of a journey to Rome and a visit to the Pope, M. Brunetière made against science the following charges: "For the last two or three centuries, science has promised to change the face of the earth, to dispel every mystery; she has not done so. She is powerless to resolve the sole problems that are essential, that concern the origin of man, the rules for his conduct, and his future destiny. We know now that natural science can teach us none of these matters. Thus, in the battle between science and religion, science has been defeated, because she has had to admit her powerlessness precisely where religion is most strong. For religion gives the solutions that science has failed to supply. Religion teaches us what we can learn neither from anatomy nor from physiology, that is to say, what we are, whither we are going, and how we ought to act." This quotation from Brunetière seems to me to show how far he is from appreciating the scientific spirit. Science has made no such promises as he describes, she is far too humble to promise to dispel every mystery. The scientist will investigate only such questions as seem to be amenable to the scientific method, and will refuse to deal with those on which he has no evidence whatever, on the simple ground, *Non possumus*. The physiologist cannot dissect out the soul from the brain, neither can the physicist weigh it, nor the chemist find its reaction

on protoplasm. The scientist knows of no way of approaching the question of man's future existence, but this does not prevent him from inquiring what life is, and how it originates, although he has not progressed very far in this direction. Science is far less concerned with the question as to whether we shall live forever than with the question of the worth of the present life, and here she certainly makes a positive contribution. As to man's conduct, every conclusion of science teaches us to live so that the condition of the whole of society shall improve and develop as Nature manifestly intends it to do. Against every kind of waste, due to the infraction of Nature's laws by any form of sin or inefficiency science cries out in protest. She prefers to show by her example the blessedness of work in the present, rather than to mourn her lack of knowledge of the future. What religion can do in these matters that science cannot it would be difficult to show.

Like Brunetière in his denunciation of science is Tolstoy. "All that we call culture," says the great Russian, "our sciences, our arts, improvements in the amenity of life, are no other than attempts to deceive the moral cravings of mankind; all that we call hygiene and medicine are no other than attempts to deceive the physical and natural cravings of mankind. The whole progress of science up to the present time has not only not improved the lot of the majority of mankind, that is to say of the laborers, but has made it worse." I am free to say that I should consider it unfair to charge these pessimistic utterances to the account of religion, but prefer to treat them as vagaries of an intellect much tortured by beating against the rocks of doubt.

Allow me then in closing to present the creed of at least one scientist:

He believes that this world is good and reasonable, that it is subject to law, that it eternally progresses, and that all progress is good. He believes in the dignity of man, that man may understand the world, from the electrum, the atom, and the molecule to the remotest star, that he may improve himself without limit, and that life is worth living. He believes that work is good and that wasting his inheritance of time is sin. He believes that if he has done his work well he need not fear what shall come when it is done. And finally he believes that only by searching can he find out God.

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